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**THE TARGET ZONE MODEL AND ITS
APPLICABILITY TO THE RECENT EMS
CRISIS**

Bas van Aarle

FEW 624

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Communicated by Prof.dr. H. Huizinga



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The target zone model and its applicability to the recent EMS crisis.

Abstract

The target zone model provides a rich toolkit to analyze many different aspects associated with many forms of exchange rate management. This article summarizes in an informal as possible way the basic theoretical insights that the target zone model is able to generate. With these insights a closer look at the recent EMS crisis is then undertaken in order to understand the basic forces that are at work in the EMS. After a prolonged period of remarkable stableness of the exchange rates in the EMS, from September 1992 onwards, exchange rates became under strong speculative pressures, which made a number of parity changes and other adjustment measures inevitable. Increasing divergences between EMS exchange rates and equilibrium exchange rates, i.e. exchange rates that would reflect fundamental forces in the EMS, are seen to drive the speculative attacks in the EMS. The recent speculative attacks on the EMS, in our opinion, must be considered as evidence for the fact that, despite the prolonged period of remarkable exchange rate stability, certain imbalances between EMS participants have developed themselves and have made a renewal of the parity grid inevitable. Rational speculation by a forward looking public has caused the ultimate collapse of the outdated parities.

Key-words : target zones, speculative attacks, EMS.

JEL-code : 130, 420, 430

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§1. Introduction

This paper seeks to find an explanation for the EMS crisis, both from theoretical analysis and empirical evidence on theory. Exchange rate dynamics in a target zone like the EMS are explained in the *target zone model*, which with several extensions serves as the main analytical tool in our theoretical analysis. The target zone model explains how a target zone can contribute to exchange rate stability between the participating countries. If exchange rate fundamentals between countries, however, diverge over time, unavoidably a critical point will be reached where a speculative attack is launched against the target zone. Our interpretation of the recent EMS-turmoil presumes that this critical point was reached in the recent crisis. In the empirical part, target zone credibility is tested. Using interest rate differentials between the participating countries, it is shown that the target zone commitments of most EMS countries became less and less credible throughout the recent EMS crisis.

The countries participating in the EMS are characterized by increasing interdependencies in real -, financial -, and monetary aspects. These increasing interdependencies and proceeding integration induce the need for a higher intensity of macroeconomic policy coordination and regulation to resolve the also increased likeliness of the occurrence of conflicts between macroeconomic policies and macroeconomic policymakers of the participating countries. The EMS in principle, provides a set of rules and tools that foster coordination of in particular monetary policies. There is a continuous tension between sticking to these rules and the temptation to use discretionary policies to increase domestic welfare at the costs of a partial circumvention of EMS commitments. Financial markets can be considered to evaluate continuously the credibility and sustainability of the EMS commitments: they are involved in a non-cooperative target-zone game with the Central Banks of the EMS countries. In situations where credibility and sustainability become doubtful, financial markets test the ability and inclination from the Central Banks to defend the target-zones, inducing large speculative capital flows.

The EMS is a subphase in the entire process of the envisaged European economic integration, a process that is expected to proceed with the formation of a European Monetary Union (EMU) which no longer allows for parity realignments, and, finally, the establishment of a European Central Bank (ECB) which independently determines European monetary policy that creates a European money, which replaces the currencies of the individual EMS members. In the light of the present EMS turmoil, it remains doubtful whether this ambitious program can be carried out

successfully with the current degree of macroeconomic convergence and - policy coordination.

This paper introduces the aspects which were considered to be most important in understanding and explaining the recent turmoil in the EMS. §2 introduces the workings of the target zone model by summarizing the results of the literature. It is shown how exchange rate dynamics in a target zone like the EMS are driven by exchange rate fundamentals and the degree to which the target zone commitments that the monetary authorities are deemed credible. Attention is devoted to the causes and consequences of speculative attacks on a target zone, of realignments and of changes in the bandwidth. §3 consists of an empirical application of the theoretical target zone model when we investigate EMS credibility.

§2. The target zone model and its extensions.

A credible target zone is able to lessen *exchange rate volatility* is one of the basic results of the target zone literature. A lower degree of exchange rate volatility is in general believed to affect positively real and financial integration and by that social welfare. Many empirical studies have been carried out to test whether the EMS has induced a lower degree of exchange rate volatility. There is a fairly high amount of evidence that since the start of the EMS the intra-EMS exchange rate stability has significantly increased, both with respect to a short-term - as a long-term time horizon, see e.g. Rogoff [1985]. Within this respect the European Monetary System has been successful. Besides the likely positive effects from decreased nominal exchange rate variability, two unintended side effects of such a lower degree of nominal exchange rate volatility can possibly be induced, namely, *higher nominal interest volatility and higher real exchange rate volatility*. Rogoff [1985] also finds evidence for an increase in real exchange rate volatility after the introduction of the EMS.

The basic target-zone model can be derived by considering domestic and foreign monetary equilibrium in the following, simple monetary model:

$$m_t - p_t = k.y_t - \gamma.i_t + \epsilon_t \quad (1)$$

$$m_t^* + p_t^* = k.y_t^* - \gamma.i_t^* + \epsilon_t^* \quad (2)$$

$$i_t = i_t^* + \frac{E_t(ds)}{dt} \quad (3)$$

$$p_t = p_t^* + s_t \quad (4)$$

$$m_t = d_t + R_t \quad (5)$$

Where m_t and m_t^* denote (logarithms of) home and foreign money supply, p_t , p_t^* domestic and foreign price level, i_t and i_t^* domestic and foreign interest rate and y_t , y_t^* domestic and foreign income, d_t credit of the Central Bank to the banking sector and government, R_t are foreign exchange reserves at the Central Bank, γ is the interest elasticity of the money demand function and k the income elasticity of money demand. The expectation operator $E(.)_t$ is conditioned on the current information-set Ω_t that includes the values of past exchange rates and of past and current exchange rate fundamentals. s_t forms the spot exchange rate between domestic and foreign currency and its derivative w.r.t. time $E_t(ds) / dt$ is equal to the expected depreciation. ϵ_t and ϵ_t^* are random shocks that impinge on monetary equilibrium in both countries.

Money market equilibrium in the home and foreign country is described in eq.(1) and (2) respectively and seen to depend on the domestic (foreign) rate of interest and domestic (foreign) income and random shocks². Real income is typically assumed to be constant in the monetary approach at some equilibrium level and a frictionless price system continuously adjusting any difference between ex ante demand and supply in the real economy.

According to the uncovered interest rate parity condition, eq. (3) domestic and foreign bonds are perfect substitutes, while the purchasing parity condition of eq. (4) ensures perfect goods market arbitrage between the domestic and foreign economy. Eq. (5) describes the Central Bank's balance sheet, according to which nominal money is equal to credit provided by the Central Bank to domestic institutions (banks and central government) and foreign reserves at the Central Bank. The balance sheet provides a convenient way to describe different forms of monetary policy:: *unsterilized interventions* imply a change in R_t accompanied by an equivalent change in m_t ,

² Mark that the form of domestic and foreign real money demand as in eqs. (1) and (2) assumes that no currency substitution between domestic - and foreign money takes place. Currency substitution would imply that foreign variables influence the demand for domestic money demand as well. The implied loss of stability and predictability of domestic money demand would affect the independence and effectiveness of domestic monetary policies.

sterilized interventions entail a swap between R_t and d_t to prevent an increase in m_t , *open market operations* are carried out to stabilize interest rates and entail a swap between m_t and d_t .

Subtracting foreign money market equilibrium from domestic money market equilibrium, after incorporating UIP and PPP, yields an equilibrium pricing condition in the foreign exchange market:

$$s_t = m_t - m_t^* + v_t + \gamma \cdot \frac{E_t(ds)}{dt} \quad v_t = k.(y_t^* - y_t) + \epsilon_t - \epsilon_t^* \quad (6)$$

according to which the exchange-rate is driven by fundamentals in the form of divergences in money supplies and money demand and by exchange rate expectations. For the sake of convenience, we denote by f_t *exchange rate fundamentals at time t*, i.e. $f_t = m_t - m_t^* + v_t$.

The EMS system prescribes a central ECU parity, c , for all the participating currencies and for these parities critical upper and lower bands are determined, between which the exchange rates are allowed to fluctuate³:

$$s_L \leq s_t \leq s^U \quad (7)$$

The EMS system prescribes two important instruments the monetary authorities are expected to use in order to defend the target zone upon which they have committed themselves and to counteract speculative pressure when exchange rates reach target zone boundaries: *interventions* and *interest rate targeting*. Besides these measures to keep the exchange rate inside the bands, a *realignment of the parities* is prescribed in a situation where current parities are considered no longer to reflect the underlying fundamental variables in the EMS countries. Persistent inflation - and growth differentials in the EMS would form clear indicators of divergences in fundamentals. A realignment provides the possibility to enhance structural adjustment in the EMS when persistent divergences in exchange rate fundamentals are present.

³ Pesach & Razin [1992] consider a form of a target zone in which monetary authorities target *the rate of exchange rate depreciation* :

$$(0 \leq) \frac{ds}{dt} \leq \left(\frac{ds}{dt}\right)^U$$

Often, such target zones -*crawling pegs or tablita's* are they also called- where the heart of many disinflation strategies in high inflation countries. A credible crawling peg displays a similar nonlinear relation between exchange rates and fundamentals as an ordinary target zone : instead of nonlinearity in the relation between exchange rate levels and levels of fundamentals there is a nonlinear relation between exchange rate depreciation and rate of growth of fundamentals.

Figure 1 graphs exchange rate behaviour inside a credible target zone as a function of exchange rate fundamentals and exchange rate bands:

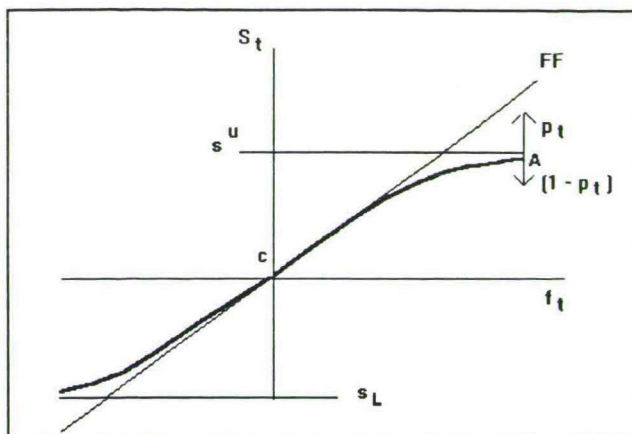


Figure 1. A credible target zone.

The exchange rate is seen to be stabilized when it approaches the critical upper - and lower bound: the financial markets at time t consider a probability $(1 - p_t)$ of a successful defending of the target-zone by the authorities, which automatically stabilizes the actual exchange rate the more close the exchange rate gets to the target zone bands, via the γ -term on the RHS of eq.(6). Full credibility of the target-zone implies a zero probability, p_t , that the monetary authorities are unable or unwilling to defend the target-zone and give up the existing target-zone in exchange for a free float or a new parity. This "change in regime or collapse probability" will be important in the next sections and determines the degree of non-linearity of the solution of exchange rates as a function of fundamentals. In fact, the nonlinear relation between exchange rates and fundamentals in figure 1 is drawn *given* a value of p_t that determines the degree of nonlinearity in this relation. If this probability increases, the target-zone increasingly loses its nonlinear stabilizing component in exchange rate formation: if p_t approaches 0.5 the relation between exchange rates and fundamentals approaches the free float or fundamentals' solution. If this probability decreases the relation increasingly takes the nonlinear S-shaped form⁴. When p_t is larger than 0.5 the S-shaped curve of fig.1. is inverted in the 45° line and the relation between exchange rate and fundamentals is referred to as the "inverted S-shape."

⁴ Figure 1 is drawn for zero or small values of μ : higher values of μ decrease the degree of nonlinearity directly.

The stabilization at the upper - and lower bounds of a credible target zone is referred to as 'smooth pasting'⁵ or 'the honey-moon effect'. The FF line in fig. (1) displays exchange rate dynamics as a function of exchange rate fundamentals in the absence of a (credible) target zone system: it will be referred to as the *free floating - or linear solution*. When p_t is less than 0.5, a form of anomalous exchange rate behavior is present in a target zone : exchange rates are destabilized when approaching target zone bands. The occurrence of such a behavior is referred to, the 'divorcement effect' (Bertola & Caballero [1992]). Unless otherwise indicated, we will assume that p_t is less than 0.5.

Solving eq.(6) forward, subject to eq.(7), and choosing the unique convergent solution, results in:

$$s_t = \frac{1}{\gamma} \cdot E_t \int_t^{\infty} [(m(\tau) - m^*(\tau)) + v(\tau)] \cdot e^{\frac{t-\tau}{\gamma}} d\tau \quad s.t. \quad s_L \leq s_t \leq s^U \quad (8)$$

according to which exchange rate is equal to the present value of future fundamentals *given the critical upper- and lower bands*. The dynamic process of the fundamentals can be chosen to have various forms. Often encountered forms are zero growth rate of fundamentals, constant growth rate and mean-reversion in fundamentals. A specification that allows for these three dynamic processes is:

$$df = \mu \cdot dt - \rho \cdot (f_t - f_0) + \sigma \cdot dz \quad \sigma \geq 0 \quad (9)$$

according to which the difference between foreign - and domestic fundamentals grows at a constant rate μ plus a mean reverting element for positive values of ρ -and mean-averting for negative values of ρ - plus a identically, independently and normal distributed stochastic process z with zero mean and variance σ^2 . f_0 denotes some long-term equilibrium level of fundamentals, which could be thought to be equal to a level of fundamentals f_c that corresponds with the central parity of the target zone. The dynamic process of eq.(9) could either result from dynamics of the relative money supply ($m_t - m_t^*$) or relative velocity $k \cdot (y_t^* - y_t) + \epsilon_t - \epsilon_t^*$, or as some linear combination of both.

The general solution of exchange rate behaviour in a credible target zone model as found in eq.(8) can be written as a function $g(\cdot)$ of its fundamentals f_t solely. If ρ is assumed to be equal to 0 for simplicity, applying Ito's lemma to the expected exchange rate in eq.(6), yields:

⁵The mathematical conditions for smooth pasting are $g'(f^U) = 0$ when $s^U = g(f^U)$ and $g'(f_L) = 0$ when $s_L = g(f_L)$.

$$\frac{E(ds)}{dt} = g'(f_t) \cdot \mu + 0.5 \cdot g''(f_t) \cdot \sigma^2 \quad (10)$$

Substituting this outcome back into eq.(6) and solving for f_t , finally gives our basic result, which determines the exchange rate at time t as an explicit function of the fundamentals f_t and the upper and lower target zone band lower and upper target zone boundaries:^{6 7}

$$s_t = f_t + \gamma \cdot \mu + A_1 \cdot e^{\lambda_1 f_t} + A_2 \cdot e^{\lambda_2 f_t} \quad (11)$$

in which λ_1 and λ_2 are the positive and negative roots of:

$$\lambda^2 \cdot \gamma \cdot \frac{\sigma}{2} + \lambda \cdot \gamma \cdot \mu - 1 = 0 \quad (12)$$

The integration coefficients A_1 and A_2 depend on the boundary conditions on exchange rates s_L and s^U as a consequence of the target zone commitment, or equivalently, on the critical lower and upper level on exchange rate fundamentals, f_L and f^U , and are determined by solving simultaneously the following system of four equations in four unknowns A_1 , A_2 , f_L and f^U :

$$s^U = f^U + \gamma \cdot \mu + A_1 \cdot e^{\lambda_1 f^U} + A_2 \cdot e^{\lambda_2 f^U} \quad (13)$$

$$s_L = f_L + \gamma \cdot \mu + A_1 \cdot e^{\lambda_1 f_L} + A_2 \cdot e^{\lambda_2 f_L} \quad (14)$$

$$0 = 1 + \lambda_1 \cdot A_1 \cdot e^{\lambda_1 f^U} + \lambda_2 \cdot A_2 \cdot e^{\lambda_2 f^U} \quad (15)$$

$$0 = 1 + \lambda_1 \cdot A_1 \cdot e^{\lambda_1 f_L} + \lambda_2 \cdot A_2 \cdot e^{\lambda_2 f_L} \quad (16)$$

Exchange rates in a target zone, consequently, are found to depend on both exchange rate fundamentals and on the degree to which the target zone commitment made by the authorities is credible. This credibility component translates itself into the values of A_1 and A_2 and determines

⁶ The derivation of this result can be found in Froot & Obstfeld [1991].

⁷ When $\rho \neq 0$, exchange rates as a function of fundamentals are characterized by a s.c. confluent hypergeometric function $M(\cdot; \cdot; \cdot)$

$$s_t = \frac{(f_t + f_0 \cdot \rho \cdot \gamma)}{1 + \rho \cdot \gamma} + A_1 \cdot M\left(0.5, \rho \cdot \gamma; 0.5; \frac{\rho(f_0 - f_t)^2}{\sigma^2}\right) + A_2 \cdot M\left(\frac{1 + \rho \cdot \gamma}{2 \cdot \rho \cdot \gamma}; 1.5; \frac{\rho \cdot (f_0 - f_t)^2}{\sigma^2}\right) \cdot \frac{\sqrt{\rho} \cdot (f_0 - f_t)}{\sigma}$$

the degree of nonlinearity in the relation between exchange rates and exchange rate fundamentals in a target zone. A credible target-zone is characterized by a negative A_1 and a positive A_2 , which gave exchange rates within the target-zone the characteristic S-shape of figure (1). In the case of a free float of the exchange rate no target-zone commitment is present, i.e. $s_L = 0$ and $s^U = \infty$, or a zero-credibility target zone ($p_t = 1$), A_1 and A_2 become equal to 0 and the exchange rate follows the free float solution FF. A credible *fixed* exchange rate system would be described by values of A_1 and A_2 that would tend to minus infinity and plus infinity, resp, in which case the relation between exchange rates and fundamentals would be described by the horizontal line through the central parity, c , that was chosen.

Speculative attacks on target zones.

Consider a situation where a country has reached the critical upper bound of the target zone and maintains a positive drift rate μ in say its domestic credit expansion, e.g. as part of inflationary financing of fiscal expansion⁸. The positive drift in exchange rate fundamentals implies that the domestic currency is inhearently weak: when the exchange rate reaches the upper - or lower bands of the target zone, continuous (unsterilized) interventions are necessary to keep the exchange rate within the band.

A continuous loss of reserves at a rate μ , due to the continuous (unsterilized) foreign exchange market interventions, is however not sustainable in the long run: without a credible stabilization program to curb expansionary domestic credit policy, a speculative attack eventually will be triggered in which remaining foreign exchange reserves are captured by rational agents who in this manner deprive the monetary authorities to defend the target zone any longer. A target zone can be considered *sustainable in the short run* as long as the amount of time before the collapse is strictly positive.

A speculative attack on a target zone forms a natural extension of the extensive literature on speculative attacks on fixed exchange rate system, which originated from the seminal paper of

⁸ Inflationary financing of fiscal deficits was an often encountered phenomenon in Latin American countries. The consequent and often spectacular exchange rate collapses have inspired the speculative attack literature. Inconsistencies between public finance and exchange rate management are seen to drive the speculative attack and the eventual surge in inflation. Van Wijnbergen [1991] considers this public finance view of inflation in an open economy with macro-economic policy inconsistencies.

Krugman [1979]. The speculative attack literature derives the timing of the speculative attack from the condition that no anticipated profit opportunities occur. In the speculative attack terminology the free floating solution FF is referred to as the *shadow floating exchange rate at time t*.

The exact timing of the speculative attack is derived by applying the condition that rational speculation precludes any anticipated upward - or downward jump of the exchange rate at the time of the speculative attack. The probability of a speculative selling attack at time t is equal to the probability that the exchange rate at time t will exceed the upper target zone band:

$$p_t^{SA} = Pr(s_t \geq s^L) = Pr\left(\frac{1}{\gamma} \cdot E_t \int_t^{\infty} f_{\tau} \cdot e^{\frac{t-\tau}{\gamma}} d\tau \geq s^L\right) \quad (17)$$

Equivalently the attack probability can be defined as the probability that foreign exchange reserves will become equal or less than the minimum amount necessary to keep the exchange rate within the band:

$$p_t^{SA} = Pr(R_t \leq R_{\min}) \quad (18)$$

The closer the exchange rate approaches the target zone band the larger this probability becomes : an ever smaller positive shock on fundamentals can induce a rational speculative attack and to collapse the target zone. Figure (2) displays graphically the occurrence of a speculative attack on a target zone:

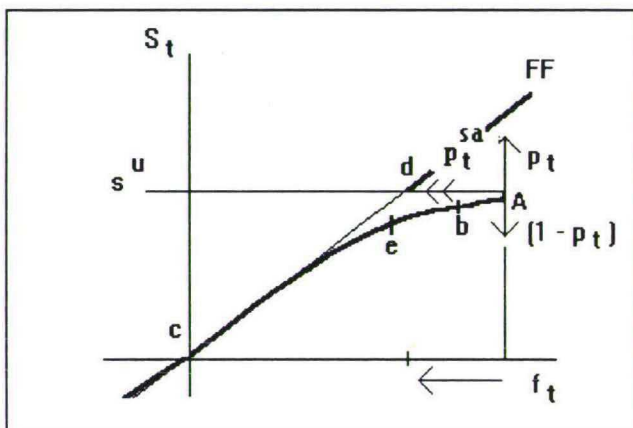


Fig.2 Speculative attack on a target zone.

Unsterilized intervention at e.g. point (b) drags the exchange rate deeper into the target zone, to (e) say. *Infra-marginal intervention* of this kind is usually considered to form the main part of

official intervention by EMS Central Banks. The degree to which such interventions can be carried out is in principle rather limited:⁹ Central Bank reserves are limited and speculative flows can reach high levels in a liberalized financial system. When the level of remaining reserves falls to a critical lower level R_{\min} , a speculative attack becomes inevitable, bringing the exchange rate and fundamentals on the free float locus FF. Such a selling attack on the domestic country takes place at point (A) in figure (2) where a discrete drop in fundamentals from (A) to (d) as a consequence of a discrete drop in money demand -the speculative attack- is experienced. The exchange rate then starts to depreciate along the free floating solution at a rate μ .

At point (A) the speculative attack probability, p_i^{SA} , becomes equal to 1 and the speculative attack is seen to occur. The speculative attack resolves the uncertainty whether the authorities will successfully defend the target zone: at point (d) the collapse - or no defence probability p_i that was introduced before has become equal to 1: the monetary authorities are no longer able to defend the target zone. The timing of the speculative attack with rational speculation is exactly such that no anticipated jump in the exchange rate at the moment of the attack is experienced. An attack before the critical lower floor in reserves at (A) has been reached, or a speculative attack after (A) would cause such an anticipated jump to occur and are therefore ruled out by assumption.

Delgado & Dumas [1993] derive the necessary amount of Central Bank reserves when exchange rates hit upon precommitted targets such as to forestall a speculative attack on a fixed exchange rate system, a one-sided target-zone and a two-sided target zone, allowing for different widths of the band. The minimal amount of foreign exchange reserves necessary to prevent a speculative attack critically depend on the structural form of the target zone: one-sided/two-sided and the width of the band. Moreover, the amount of necessary reserves is seen to depend on the envisaged exchange rate management after a speculative attack. This difference of after-attack systems can be illustrated by the different systems that prevailed in Italy and Spain e.g.: the Lira is freely floating while the Peseta has been realigned. If during the period after the collapse with freely floating exchange rate, the Central Bank is able to accumulate sufficient reserves and credibility, it might consider reentering the target zone again at a new parity and/or fluctuation margins. The minimal amount of reserves to forestall a speculative attack on a two-sided target-zone is equal to the horizontal distance between the free floating solution FF and the curve that describes exchange rate behaviour in a target zone. As already explained, at point (A) in fig.(2) reserves hit upon this

⁹ The EMS provides some limited possibilities to borrow foreign exchange reserves from a pool of EMS Central Bank reserves, but these facilities are limited and costly by their nature.

critical minimum amount of reserves and a speculative attack is induced.

A target zone, to summarize, allows the exchange rate inside the target zone to diverge from the exchange rate fundamentals. Foreign exchange reserves scarcity implies that this difference cannot exceed a critical upper level since when reaching such a critical level speculative selling attack on the domestic currency by rational speculators is inevitable. The speculative attack deprives the monetary authorities of the remaining foreign exchange reserves and the possibility to defend the target zone any longer. Instead of explaining the speculative attack in terms of reaching a critical difference between the exchange rate in the target zone and the shadow floating exchange rate level, or in terms of foreign exchange reserves reaching a critical lower level R_{\min} , the analysis could equally well be phrased in terms of fundamentals reaching a critical upper or lower level, f^U and f_L , respectively.

The actual speculative attacks in the EMS more or less confirm the theory: after several small-scale attacks that were successfully answered by interventions from the monetary authorities of the currencies involved, a final huge speculative attack was induced, which depleted foreign exchange reserves almost entirely necessitating a regime switch in exchange rate policies by the monetary authorities. From official sides, it was repeatedly asserted during the EMS crisis that the speculative attacks were undue and not justified when considering fundamentals. The problem of such "unwarranted speculative attacks" is closely connected with the increasing integration of financial markets in the EMS area and the intrinsic. The abolition of remaining controls on short-term capital flows makes it possible that a country that firmly pursues non-inflationary policies and sticks to the rules of the EMS, is confronted with large capital outflows and reserve losses, ultimately necessitating a parity change, though there is no apparent macroeconomic rationale for such a speculative attack. The "unwarrantedness" of speculative attacks can be interpreted as a dispute between policymakers and public about the true values of exchange rate fundamentals at time t .

The credibility of the EMS commitment of an individual country is determined in part by the credibility of its monetary policy and reputation of its monetary policymakers but also to a large extent by the credibility of the EMS system as a whole, *systemic credibility* so to speak: there is an important role in the EMS for shared credibility. Since the establishment in 1979, probably a quite substantial increase in systematic credibility was achieved, witnessing the decreasing number and volume of realignments, in particularly since 1985. Recently, however, this systemic

credibility probably has received a strong attack in the financial markets, which has forced a round of layoffs from the EMS (UK, Italy), devaluations (Spain, Portugal, Ireland) and widening of target zones (Belgium, Denmark, Ireland, Spain, Portugal, Greece).

Realignments : the Bertola-Svensson model.

A realignment of existing parities provides the EMS system with an instrument to enhance structural adjustment in the case where the existing parities appear not to reflect underlying fundamental developments between the EMS countries, in particular one could think of inflation - and real growth differentials. A periodic realignment in particular corrects for the gradual real appreciation of currencies of countries with a relatively high rate of inflation: without realignments their inflationary stance would induce a continuous loss of competitiveness. The expected rate of exchange rate depreciation $E_t(ds) / dt$ is equal to the *expected rate of depreciation* within the band $E_t(dx) / dt$ plus the *expected rate of realignment or devaluation* $E_t(dc) / dt$, which is referred to as g_t ¹⁰ :

$$\frac{E_t(ds)}{dt} = \frac{E_t(dx)}{dt} + \frac{E_t(dc)}{dt} = \frac{E_t(dx)}{dt} + g_t \quad (19)$$

Bertola & Caballero [1992] consider a time-varying probability measure p_t that measures the probability that the exchange rate will be realigned at time t . With a probability $(1-p_t)$ the target zone is expected to be defended successfully and no realignment to occur. p_t is called the *realignment - or devaluation probability at time t* and is in fact a special form of the general notion of a regime switch probability p_t at time t , as introduced in the beginning of this section. The rate of realignment at time t , q_t is also a random variable. The expected rate of realignment is equal to the realignment probability times the rate of realignment and is assumed to follow some stochastic process, e.g. a random walk plus trend:

¹⁰ Note that the position of the exchange rate within the band at time t , x_t is equal to the spot rate at time t minus the central parity at time t : $x_t = s_t - c_t$.

$$g_t = \frac{1}{dt} (p_t \cdot E_t(dq) \cdot dt) \quad (20)$$

$$dg_t = \mu_g \cdot dt + \sigma_g \cdot dz_g \quad (21)$$

Exchange rates as a function of fundamentals and expected rate of realignment can then be solved by substituting eq.(18) using eq.(19), in eq.(1), and follow the same solution approach, which yields:

$$s_t = f_t + \gamma \cdot \mu + \gamma \cdot g_t + A_1 \cdot e^{\lambda_1 \cdot (f_t + \gamma \cdot g_t)} + A_2 \cdot e^{\lambda_2 \cdot (f_t + \gamma \cdot g_t)} \quad (22)$$

As compared to the credible target zone model with zero-devaluation probability, a positive devaluation probability induces a positive expected rate of realignment that influences exchange rate behaviour in a target zone. The target zone model that allows for stochastic devaluations is sometimes referred to as the target zone model with imperfect credibility, to distinguish it from the original Krugman model that is based on a zero realignment probability. The next figure illustrates graphically a periodic realignments of the central parity from c to c' and from c' to c'' :

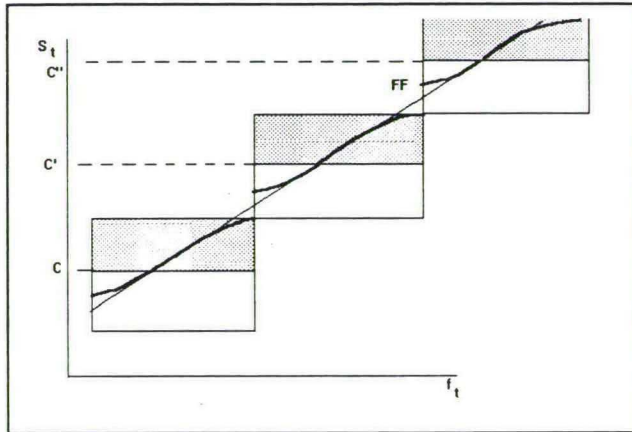


Figure 2. Realignments of a target zone.

In practice, several instances were noticed where EMS countries with a weak currency, opposed to a devaluation of their parities by fear of losing the imported anti-inflation reputation from Germany. Such blocking of structural adjustment from a parity change, when exercised for a long period, can induce severe distortions in the real side of the economy. While intended to defend EMS commitments in the short-run, such adjustment blocking policies can undermine the proper

working of the system in the long run, a problem that the recent EMS crisis seems to hint at.

Exchange rate behaviour in the band allows us to infer the degree of credibility of the target zone. A credible target zone is characterized by low-exchange rate (in the band) volatility and the frequency of x_t is relatively higher at the boundaries as compared to intervals close to the central parity: the frequency distribution of x_t is U-shaped. These are necessary conditions of the S-shaped relation. Low target-zone credibility, reflected in an inverted S-shape of the relation between exchange rates and fundamentals consequently implies an inverted U-shaped frequency distribution of the exchange rate in the band: the exchange rate within the band has relative frequencies near the central parity and displays high volatility at the target zone boundaries. By drawing the frequency distribution of x_t , more insight in the degree of target zone credibility can thus be obtained.

Changing the bandwidth of a target zone.

The consequences of narrowing and broadening target zones are important to consider given the process of narrowing of target zones that some EMS countries have experienced and in particular considering the recent the decision to broaden the bands of all currencies except the Dutch Guilder from 2.25% to 15%. This widening of the target zones was decided upon as a compromise given the opposition of realignments from many countries. It remains to be seen whether such a periodic widening and narrowing of target-zones is a very good measure to let the EMS function efficiently. Delgado & Dumas [1992] analyze the effects of changing the width of target zone bands. Changing the width of the target zones, as follows from eqs.(13)-(16), leads to different values of the integration constants A_1 and A_2 in eq.(10), on its turn inducing a different nonlinear relation between exchange rates and fundamentals within the new bands as compared to the former bands. Financial markets at time t consider the probability p_t of an instantaneous narrowing / widening of the target zone: this *change in target zone width probability at time t* , is a particular form of the regime switch probability that as defined before and which was seen to determine the degree of nonlinearity in the relation between exchange rates and fundamentals in the short run. Fig. (4) illustrates the change from a broad to narrow bands at point A, while figure(5) considers the reversed change:

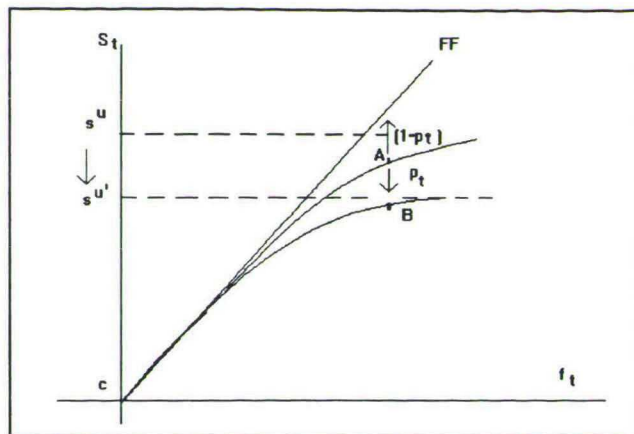


Fig. 4 Narrowing a target zone.

A narrowing of the target zone at time t (point A) as in fig.(4), where the upper band of the target zone is reduced from s^u to $s^{u'}$ and the lower band is raised from s_L to s_L' , entails a decrease in exchange rate volatility in a credible target zone. The exchange drops to point B on the new locus of exchange rate and fundamentals that describes conditions in the new (credible) target zone. The decrease in exchange rate volatility however translate itself in an increase in interest rate volatility. Obviously, a narrowing of a target zone is only feasible when the exchange rate is sufficiently far from the original upper band. The narrowing of the target zone bands of the Italian Lira in 1990 and the entrance of the British pound into the EMS are the practical cases that are associated with a narrowing of target zones.

A widening of a target zone in fig.(5) increases exchange rate volatility, since the degree of non-linearity between exchange rate and fundamentals is reduced in the short run. The exchange rate jumps up from A to point B which is the combination of fundamentals and exchange rate that is consistent with the new conditions of the target zone. Qualitatively there is no great difference between a devaluation of the exchange rate and the widening of the target zone, as can be seen by considering fig.5 and fig.3.

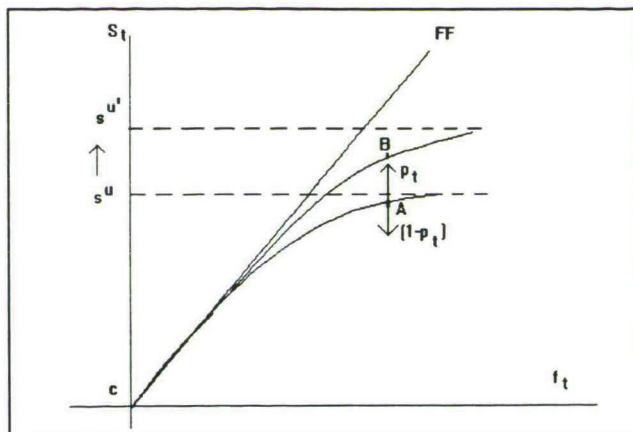


Fig.5 Widening a target zone.

In the recent EMS turmoil the widening of the target zone was seen as a less worse alternative by a number of countries than a realignment. This might seem rather odd as a devaluation of weak-EMS countries and the widening of their target zone bands does not make a great difference from a qualitative perspective; from a quantitative perspective both options differ somewhat in the degree of non-linearity in the relation between exchange rates and fundamentals after the implementation of the respective changes in the target zone, if the new target zone encounters a sufficient degree of credibility at least.

A widening of a target zone can be considered as a movement towards a target zone that resembles more and more a free float, like the situation of high devaluation expectations and low target zone credibility. This also seems the most obvious interpretation of the recent widening of the EMS target zone. A narrowing of a target zone, in contrast, implies a move towards a fixed exchange rate system. While a widening of target zone in principle is always feasible, a reversed move in the form of a tightening of the target zone is only feasible when exchange rates in the EMS are sufficiently far away from the target zone bands.

§3. A short characterization of the recent EMS crisis.

After a period of decreasing exchange rate volatility, a sudden and remarkable outburst of exchange rate volatility was experienced in the second half-year of 1992 and the first half-year of

1993. Despite initial resistance of Central Banks and repeated confirmations of politicians that exchange rate commitments would be at all costs defended, several currencies gave way: the Italian Lira and the British Pound were taken out of the EMS, the Spanish Peseta, the Portuguese Escudo and the Greek Drachma were devalued substantially in September 1992; the Scandinavian currencies who had pegged informally their currencies to the ECU, were struck by a severe attack successively and were devalued thereafter. After the Sterling depreciation, the Irish punt became increasingly overvalued: on February 1th 1993, the monetary authorities finally were forced to devalue the Irish Punt 10% after repeated attacks. With substantial efforts the Danish Krone and the French Franc could be kept inside the committed bands. In May 1993 the Peseta and the Escudo were devalued again.

On 1th August 1993, the monetary authorities of the EMS countries agreed to change the band width of all currencies except the two strongest currencies, the German Mark and the Dutch Guilder, from the former 4,5% (2,25 % above and under the central parity) to 30% (15% above and under the central parity). This dramatic change in the width of the target zone was decided upon as a consequence of a period of severe speculative selling pressures on the weak currencies. By widening of the target zone, relief from this continuous speculative pressure is sought, while not having to change central parities: a change that was fiercely refused by many EMS participants.

Table 1 summarizes the main changes in exchange rates and upper and lower bounds of the EMS target zones that have resulted because of the recent EMS crisis:

all in DM	spot rate 01/01/ 1992	spot rate 01/01/ 1993	spot rate 01/10/ 1993	upper limit 01/01/ 1992	upper limit 01/01/ 1993	upper limit 01/10/ 1993	lower limit 01/01/ 1992	lower limit 01/01/ 1993	lower limit 01/10/ 1993
1 DFL	0,89	0,89	0,89	0,91	0,91	0,91	0,87	0,87	0,87
100 BFR	4,85	4,87	4,62	4,96	4,96	5,63	4,74	4,74	4,18
100 FFR	29,28	29,35	28,77	30,50	30,50	34,62	29,16	29,16	25,68
10000 ITL	13,23	10,99	10,28	13,67	-	-	13,07	-	-
100 PES	1,57	1,41	1,24	1,63	1,46	1,47	1,45	1,30	1,09
100 ESC	1,19	1,11	0,97	1,23	1,15	1,17	1,09	1,01	0,87
100GRD	0,84	0,76	0,69	-	-	-	-	-	-
100DKR	25,70	25,88	24,74	26,81	26,81	30,44	26,81	26,81	22,58
100SKR	27,33	22,90	20,15	-	-	-	-	-	-
100NKR	25,68	23,34	22,89	-	-	-	-	-	-
100FMK	36,44	30,39	27,91	-	-	-	-	-	-
ECU	2,03	1,95	1,90	-	-	-	-	-	-
PST	2,85	2,45	2,44	3,42	-	-	2,78	-	-
IPT	2,65	2,63	2,34	2,74	2,74	2,80	2,62	2,62	2,08

table 1. EMS spot rates, upper and lower bands in DM.

Estimating the expected rate of realignment during the EMS crisis.

Realignment probabilities are likely to vary widely over time: just after a realignment the expected rate of realignment in general will be low, but when the exchange rates of weak currency countries approach the upper bounds of the target zone and no clear signs of a more restrictive domestic monetary policy are present, the expected rate of realignment is likely to increase. In a number of influential papers, Svensson, has developed a methodology to measure realignment probabilities, which decomposes total expected exchange rate depreciation in a part that measures the expected realignment and a part which measures the expected depreciation within the band: in which $E_t(dx) / dt$ forms the expected exchange rate depreciation within the band. x_t measures the deviation of the spot exchange rate from the central parity c_t , $x_t = s_t - c_t$. $E_t(dx) / dt$

$$\frac{E_t(ds)}{dt} = \frac{E_t(dx)}{dt} + \frac{E_t(dc)}{dt} \quad (23)$$

measures the expected rate of realignment of the central parity c_t . Assuming again uncovered interest parity to hold:¹¹

$$i_t - i_t^* = \frac{E_t(ds)}{dt} = \frac{E_t(dx)}{dt} + \frac{E_t(dc)}{dt} \quad (24)$$

two ways to obtain an estimate for the expected rate of realignment $E_t(dc) / dt$ are then proposed :

- *a simple method*: putting $E_t(dx) / dt$ equal to zero implies that the expected rate of realignment becomes equal to the interest rate differential,
- find an approximation for the expected depreciation within the band $E_t(dx) / dt$ which is then subtracted from the interest rate differential in order to derive a "*drift adjusted expected rate of realignment*". This method therefore is called the drift-adjustment method. The expected depreciation within the band is found by estimating:

$$\frac{x_{t+\Delta t} - x_t}{\Delta t} = \sum_i \alpha_i + \beta \cdot x_t + \gamma \cdot \delta_t + u_{t+\Delta t} \quad (25)$$

Assuming rational expectations, the forecast error term u will be orthogonal to the information set and the expected exchange rate depreciation within the band will be equal to:

$$\frac{E_t(dx_t)}{dt} = \sum_i \alpha_i + \beta \cdot x_t + \gamma \cdot \delta_t \quad (26)$$

according to which the expected rate of depreciation in the band depends on a constant, which is assumed to vary over periods between a realignment, the deviation from the central parity and the interest rate differential. Declining values of α over time suggest a lower drift in EMS exchange rates. A negative value of β implies a *mean-reverting component* in exchange rate behavior. Estimation of the expected rate of realignment over time in these both ways is often quite successful in predicting the actual realignments. Moreover, the estimation of realignment

¹¹ Alternatively Covered Interest Parity could be used to investigate target zone credibility in this approach. A target zone commitment can be considered sustainable at a time horizon of m -months, if the forward premium does not exceed the critical bound that is determined by the lower - and upper bands of the target zone :

$$f_t^m - s^U \leq f_t^m - s_t \leq f_t^m - s_L$$

where f_t^m is the m -month forward exchange rate at time.

expectations can be useful in assessing EMS credibility: higher realignment expectations clearly are an indication of declining credibility of existing EMS parities¹². In this manner the expected rate of realignment can also be interpreted as a *"time-varying" credibility measure*. Frankel & Phillips [1992] who use the first "simple method" to assess the expected rate of realignment for a time horizon of 12 months, find a marked decrease in interest rate differentials vis-à-vis Germany from 1987 onwards and conclude from this decrease a higher degree of credibility of the EMS target zone. In the period January 1990 till September 1991 interest rate differentials of all EMS currencies were found to be smaller than the target zone bands, leading the authors to presume that EMS credibility, at that time, to be higher than ever.

It is interesting to see whether the expected rate of realignment increased during the recent EMS crisis and whether it performed well in indicating the decline of credibility of the EMS commitments of the currencies involved. In Appendix B the expected rate of realignment is determined for the period January 1990 till October 1993, using the simple method, with the purpose of determining the expected rate of realignment during the recent EMS crisis. Using 3 month Euro-interest differentials vis-à-vis Germany, it is seen that the interest differentials experience a marked increase in level throughout 1992 up till levels which largely exceed the 2,25% of the target zone bands, which leads us to conclude that credibility of the EMS parities of the most countries reduced throughout 1992. Interest rate volatility also increased markedly throughout 1992 and 1993, a clear indication of the strong speculative forces that were initiated and the various reactions from monetary authorities. The turbulence during the recent EMS crisis is reflected in large movements of exchange rates and interest rate differentials, up to levels that were not uncommon in the early years of the EMS, as can be seen in Appendix A, which depicts the DM exchange rates and 3 month interest rate differentials of the countries involved and throughout the entire EMS period. The increases in interest rate differentials and volatility of interest rates clearly foreshadow the major attack on the system that followed in September 1992 and the subsequent repeated attacks and turmoil in the system. The widening of target zone bands on 1st August, which allowed for a gradual depreciation of the weak-EMS members, has put off the steam of the speculative forces, as is immediately clear from the strong decrease again in interest differentials and interest rate volatility in the EMS. In this sense the widening of the target zone must be considered successful.

¹² Given the rate of realignment, there is a unique positive correspondence between the expected rate of realignment and the realignment probability at time t . A high expected rate of realignment will imply a high realignment probability and vice versa. (Cf. eq.(20)).

§4. Conclusions

The insights from the theory of target zones allow for a good understanding of the basic mechanisms at work in exchange rate target zone. In this article we tried to put together some aspects we thought of critical importance in understanding the recent EMS crisis. In the theoretical section, the basic target zone was introduced and extensions concerning speculative attacks, realignments and changes in bandwidth successively introduced in an informal manner.

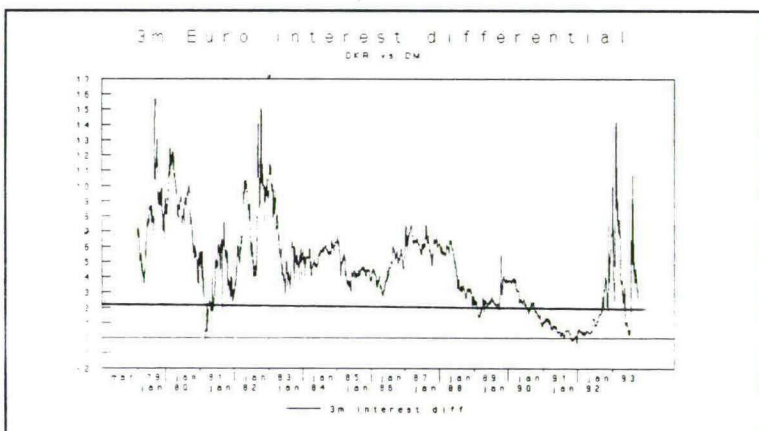
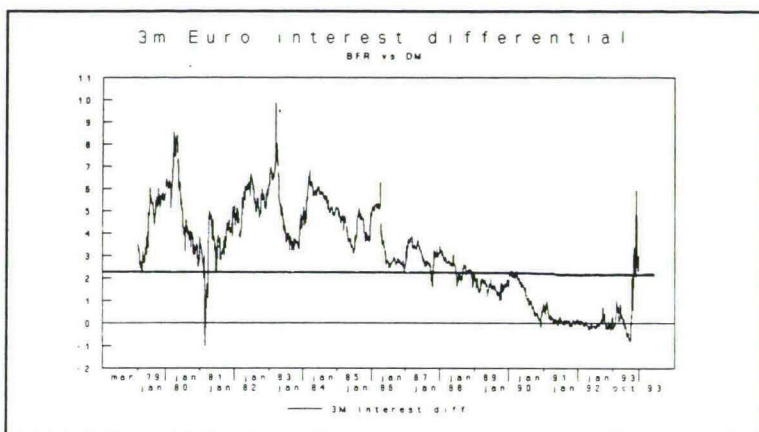
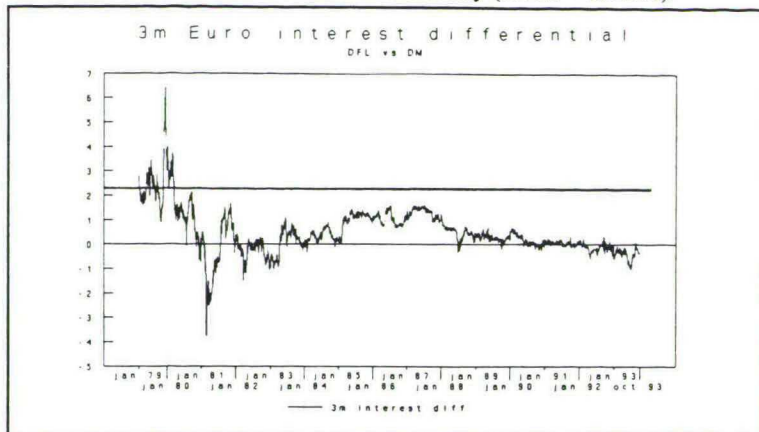
At first sight the EMS has functioned extremely well in the period 1985-1992, a period in which an unprecedented degree of exchange rate stability was achieved. Yet, the speculative attacks on several currencies, as experienced recently, remind us of the fact that the dynamics in the fundamentals still effectively determine exchange rate dynamics in the long-run. The speculative attacks reflect the speculators' rationally based conjecture that the fundamentals of the different EMS countries have thus diverged that current exchange rate parities are simply unsustainable: the speculative attacks in this view are unavoidable events.

The speculative attacks do not imply that the EMS suddenly has lost its function and possibilities, quite in the contrary, there seems to be no reason to doubt the great benefits of further intensifying exchange rate stabilization and monetary integration. What the speculative attacks do have shown is the limited ability of Central Banks to maintain unsustainable parities: unsustainable in the light of underlying monetary policies and dynamics of the real economy. The recent EMS-crisis has made clear that a target zone like the EMS is highly vulnerable to speculative attacks in a highly liberalized financial system. Credibility and consistency of macro-economic policies of the EMS-members is crucial in the persistence of monetary stability and a prerequisite on the road to further monetary integration as committed upon in the Maastricht Treaty on the European Monetary Union. The near collapse of the complete EMS system implies a considerable step backwards in the process of European economic integration. It will take considerable time and effort to restore credibility and to recapture the strong intrinsic benefits of a credible target zone. Empirical evidence was found on the decline of EMS credibility throughout 1992. The recent widening of exchange rate, after a host of speculative attacks on the system, has taken off the steam from speculative activities and caused a depreciation of the weak currencies. Exchange rates within the EMS were effectively brought closer to fundamentals by the widening of the target zone. The current target zone width is not consistent, however, with a high degree of exchange rate stability, as in is the ultimate goal of a target zone system like the EMS. The future will prove whether a return to tight bands is feasible again.

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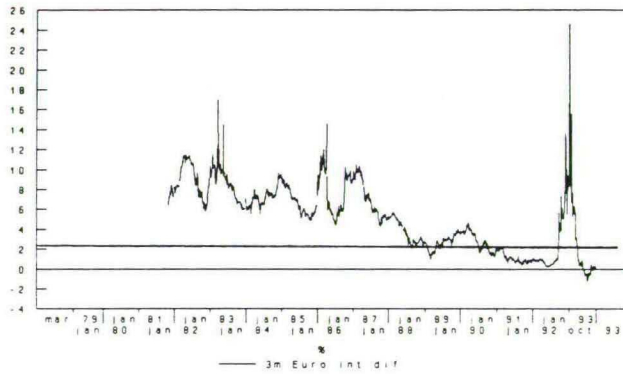
Appendix A 3 month interest differentials vis-à-vis Germany (1979:3 - 1993:10).



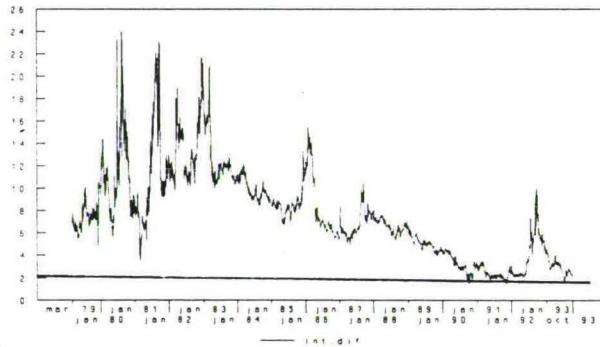
3m Euro interest differential
FFR vs. DM

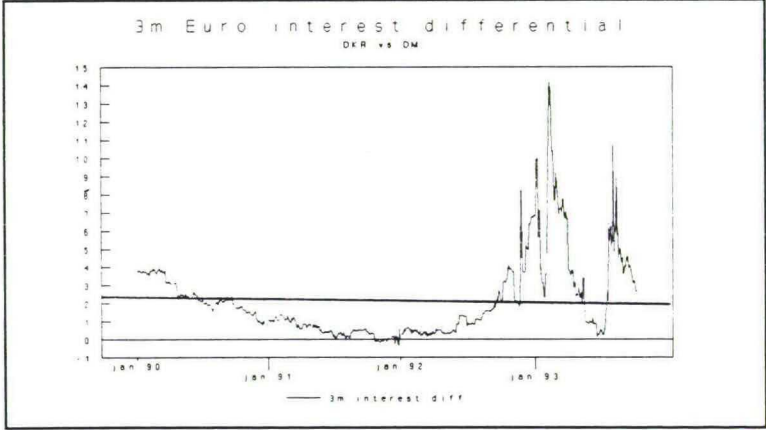
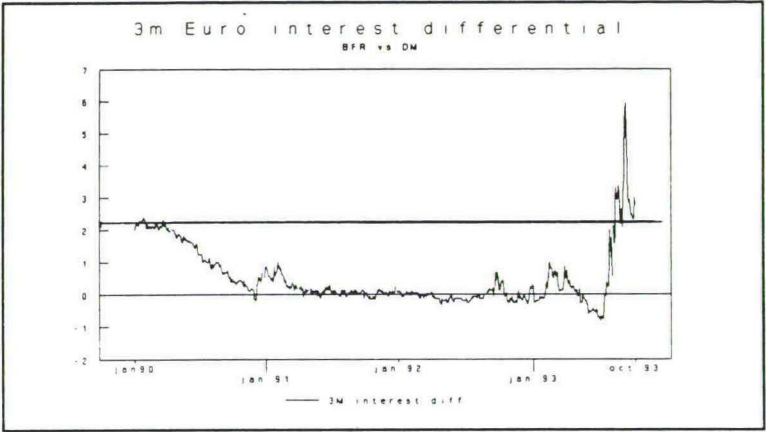
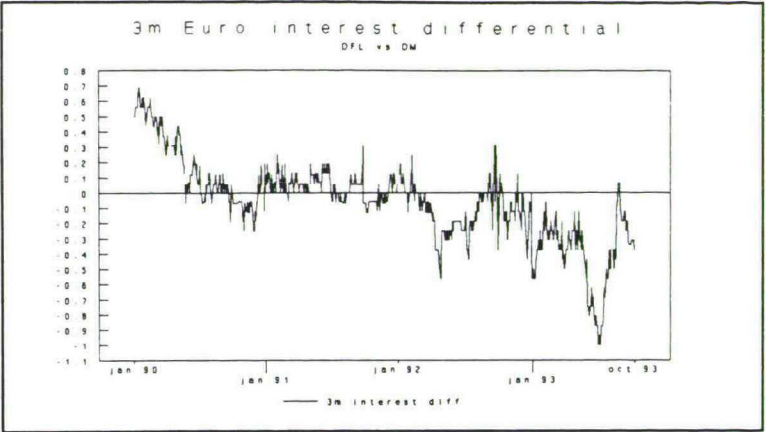


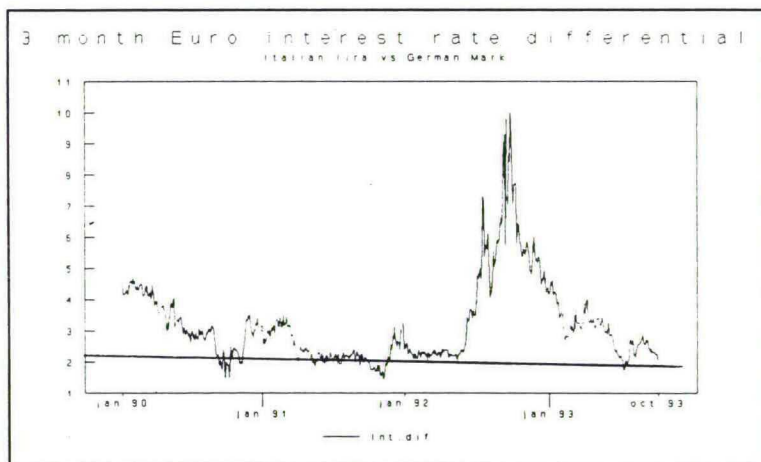
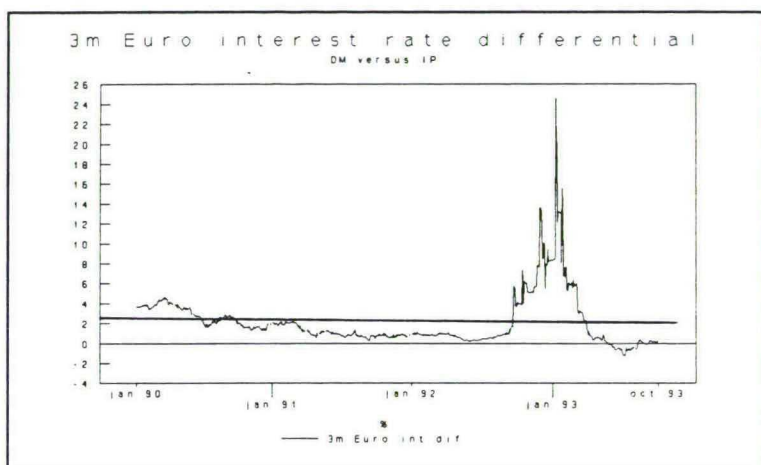
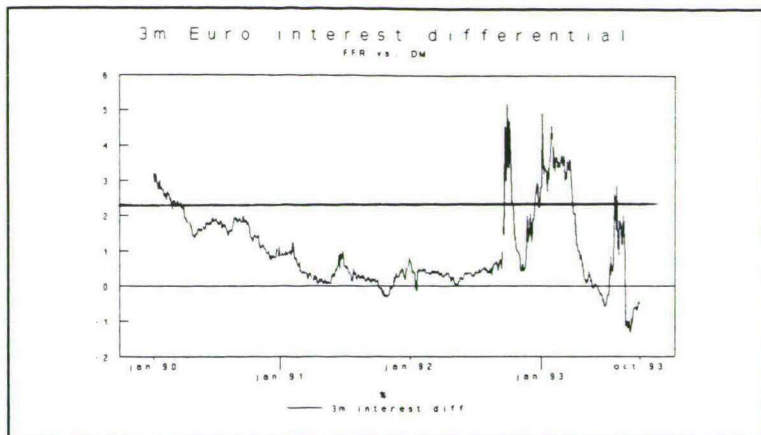
3m Euro interest rate differential
DM versus IP



3 month Euro interest rate differential
Italian Lira vs German Mark







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